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Indoor Building Fuzzy Control of Energy and Comfort Management

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Abstract: This study reports the fuzzy inference system controllers. They are employed in order to control actuator systems for thermal, visual and indoor air quality power consumption. The implementation of the Fuzzy Logic Control (FLC) system, allows an stochastic interval range of comfort index as susceptible to human body, achieving numerous power demand values for the actuator operations. The potential benefit of the automated smart building are high-level comfort, improved device efficiency, environment friendliness and reduced energy consumption as well as cost. The simulation results are shown describing the behavourial relation for each control parameter with the power consumption.

Keywords: Comfort index, energy consumption, fuzzy logic, smart building

INTRODUCTION

The global apprehensions in the increment of Greenhouse Gas (GHG) emissions and price hikes in fossil fuel resources draw unprecedented attention towards smart grid. The evolved concept of sustainable buildings with renewable energy use have potential to deal with this alarming situation. The building envelopes are emergent and are substantial consumer of the energy world around, provided increased quality living standards.

Over the past few decades energy consumption in the buildings is raised to about 40-45% of the total energy at the rate of 1.5-1.9% per annum. This is only in Europe and North America (Torcellini *et al*., 2006) and 10% per annum in china particularly electricity and also emit huge amount of GHG emissions (Torcellini *et al*., 2006; Peng *et al*., 2010).Thus, an average rise of 1% of peak demand observed in electricity networks (Lertlakkhanakul and Choi, 2008; Doukas and Patlitzianas, 2007). This high level of building energy usage and its steady increased demand in electrical network, allows designing of the energy efficient buildings with its improved energy performance.

The inhabitants spent most of their time about 90% (Benjamin *et al*., 2011) inside the building envelopes, thus ambient comfort states in a building is highly allied to the occupants' contentment (Zhu *et al*., 2010a). The necessity for the assertion of basic thermal, visual and indoor air quality comfort (Doukas and Patlitzianas, 2007; Zhu *et al*., 2010a, b; Zhun *et al*., 2010) has been increased, in the prevailing conditions of rapid price fluctuations, increased population and advanced technology. In regard to this, efforts are focused on achieving the satisfaction of energy needs for the sustainable and efficient buildings, with the assurance of operational needs with minimum possible energy cost and environmental protection (ASHRAE Research, 2009). To balance the requirements of the occupants' comfort and power consumption is the imperative issue in the control design of energy-efficient buildings (Baker *et al*., 1993).

In this study, a fuzzy logic control mechanism is developed for an indoor environmental control, to come across the energy demands. It is intended to make progress in the ambient comfort conditions, reducing the energy intake. In the building envelopes the users are central and dynamic entity and their preferences must be accounted in the control system design. The parameter ranges are provided in the control system is in acceptable limits of the users. The operation cost is in direct proportion to energy consumption. Therefore, the major objective of intelligent control design of building environment is to minimize total energy consumption. The improved level in ambient comfort state, requires more energy consumption.

BUILDING AUTOMATION AND FUZZY LOGIC CONTROLLER

An intelligent fuzzy control technique yield promising results and is applied to a substantial case in buildings (Dounis *et al*., 2011; Alexandridis and Dounis, 2007; Lah *et al*., 2005). This indicating extensive total energy consumption reduction in contrast to the existing control system, achieving the preferred comfort level. The peripheral fuzzy logic controllers are employed to satisfy various comfort

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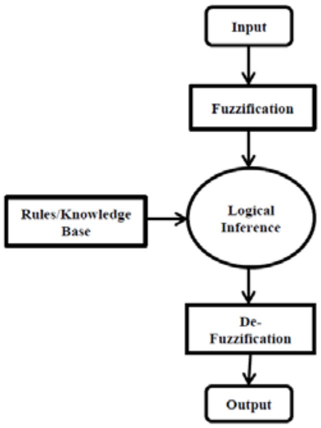

Fig. 1: Fuzzy controller block diagram

demands. There are several sources of uncertainties which ascend from real-world implications and user activities. These reservations get up from dynamic practical unknown environments of the buildings (Zhun *et al*., 2010). Thus the comfort is treated as a concept with uncertainty. The overall system optimization is the target provided through fuzzy control technique. The action of fuzzy logic control is hooked with the gains of the input and output as well as with fuzzified practice, information base and the defuzzified process as shown in the block diagram (Fig. 1).

The input to fuzzification block transforms incoming discrete values to fuzzy values and let into the fuzzy inference engine which connects knowledge incorporated with the set of rules using fuzzy approximate reasoning. Finally, the goal is to compute the discrete values from the resulting fuzzy set with de-fuzzification block.

Thermal comfort control: Thermal comfort has high impact on the inhabitants productivity and satisfaction. The Heating, Ventilation And Air Conditioning (HVAC) systems based on temperature for thermal comfort or either in multi-variable temperature and humidity control. Usually, the thermal comfort of inhabitantssensation index is addressed as Predictive Mean Vote (PMV). It is in proportionate with temperature, mean radiant temperature air velocity, humidity and clothing parameter (Zhu *et al*., 2010b; Dounis and Caraiscos, 2009). The PMV index swingsin the scale from -3 to +3. While PMV fluctuates between -0.5 and +0.5 and satisfy up to 90% of the building dwellers. The key feature in computing the PMV index is the temperature which is used to specify the thermal comfort. The only one actuator system that can be associated with both either heating and cooling systems. The fuzzy control knowledge base inference consists of two set strategies, one is comfort optimization and secondly energy consumption minimization.

Fuzzy implication: The six input fuzzy sets for error and error difference, the toolbox default triangular membership functions to linguistic variables, that are, 'NB' (Negative Big), 'NM' (Negative Medium), 'NS' (Negative Small), 'ZE' (Zero), 'PS' (Positive Small), 'PM' (Positive Medium), 'PB' (Positive Big) employed and also to the output of required power. Mamdani implication method is employed with approximate rule base reasoning (Fig. 2) along with equal preference

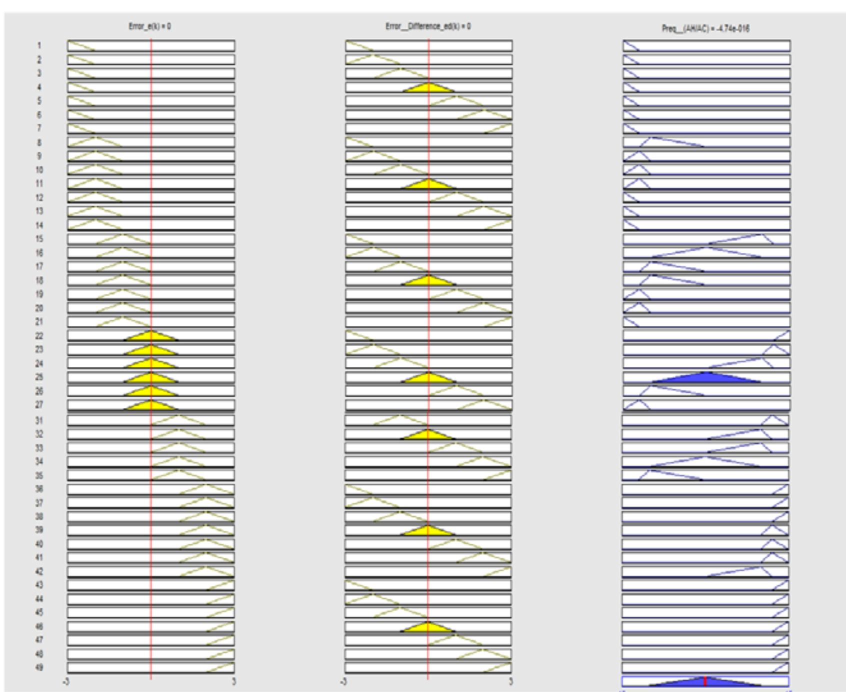

Fig. 2: Fuzzy control output representation of temperature control

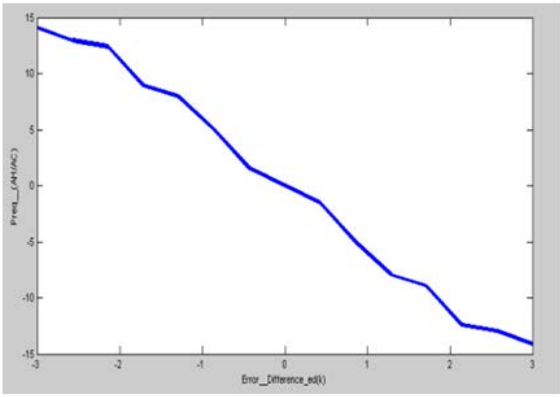

Fig. 3: Required power verses error

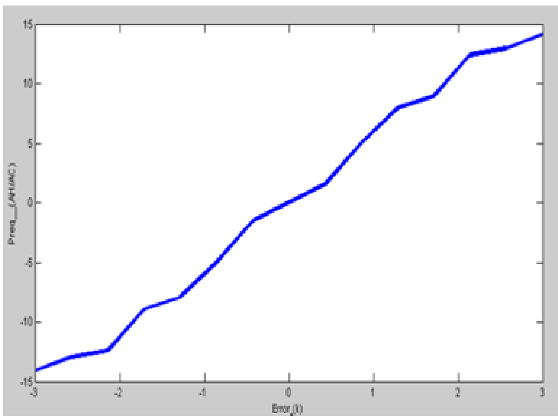

Fig. 4: Required power verses error difference

provided to each rule and thus commonly used centroid de-fuzzified method is considered. The output power will be compared to the master controller to adjust according to the power available to maintain the indoor temperature negotiated (Fig. 3 and 4) to operate actuator in order to maintain thermal comfort.

The error is the difference between set and the sensor value and the fuzzy plot for the error and the power demanded for the actuator is given in Fig. 3, which describes the direct relation as there is an increase in thermal error power demand will be increased either for heating and cooling actuators, whereas Fig. 4, describes the relation between error difference between two consecutive sensor readings and the required power for which controller behaves in an inverse relation to the Fig. 3.

Visual comfort control: The radiance level in the indoor building environment is provided to indicate the visual comfort, measured in Lux (Zhu *et al*., 2010b). Electric lighting contributesa major part of building energy consumption and are reported to consume 20-35% of the energy used in building envelopes (Benjamin *et al*., 2011; Lah *et al*., 2005). Lighting provides an attractive potential as controllable load to offer dynamic load management as important to smart grid concept. The fuzzy control is applied tothe electrical lighting system is forthe illumination control to achieve the indoor visual comfort (Dounis and Caraiscos, 2009). Since other parameters that are glare and shading are subjective and challenging to measure.

Fuzzy implication: The fuzzy sets for the error input with default triangular membership functions to linguistic variables, ‘Small’, ‘SS’ (small small), ‘BS’ (big small), ‘Ok’ , ‘SB’ (small big), ‘Big’ employed and also to output of required power of the illumination fixture. Mamdani implication method is employed with approximate rule base reasoning (Fig. 5) and commonly used centroid de-fuzzified method is considered. The power will be matched to the master controller to adjust according to the power available in order to maintain the indoor illumination comfort negotiated (Fig. 6) and to operate to the actuator to maintain the comfort.

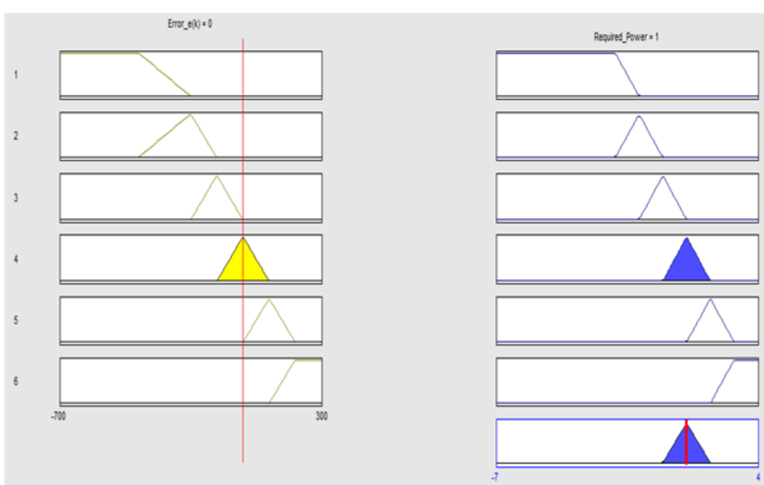

Fig. 5: Fuzzy control output representation for lighting control

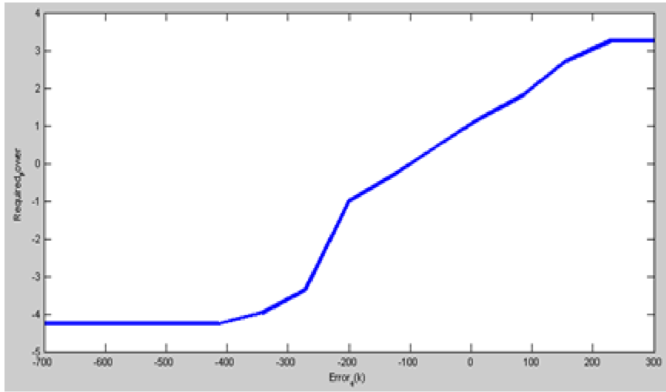

Fig. 6: Required power verses Lux

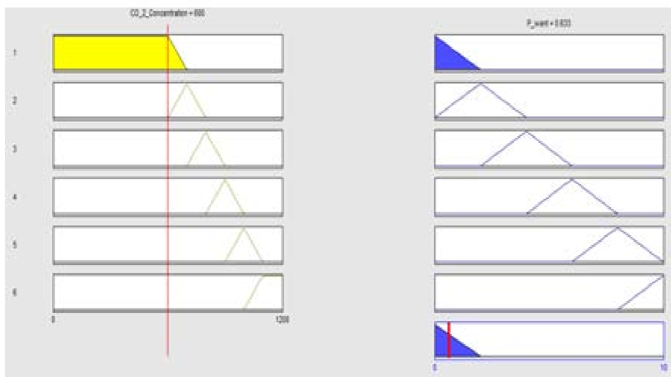

Fig. 7: Fuzzy control output representation for air quality

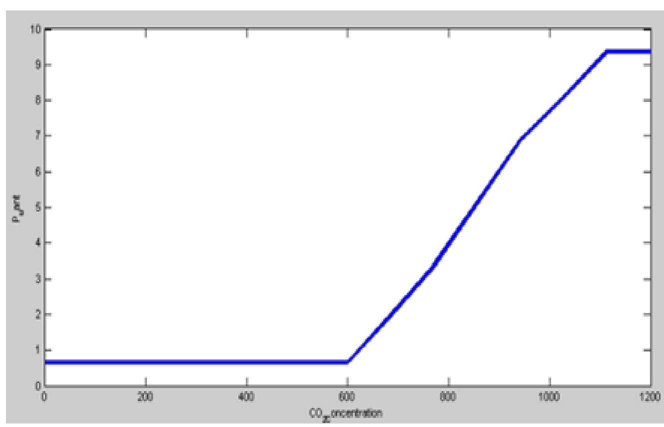

Fig. 8: Required power verses CO_2 concentration

The fuzzy plot in Fig. 6, for the visual illuminance provides steady high power demand for the huge difference in luminance and as the error decreases the power requirement is decreasing in a linear pattern.

Air quality control: The indoor envelope air quality control space is predominantly subjective with the concentration of pollutants. It is specified with the CO_2 concentration (Emmerich and Persily, 2001) and represents the presence of the dwellers and several pollution sources in the building (Zhu *et al*., 2010a). Thus CO_2 concentration is used to indicate an air quality index in the building envelope, measured in ppm. A fuzzy controller is applied to the slave air quality subsystem to compute the power demand for the ventilator. The input of the local slave fuzzy controller is error among the outside concentration and the internal set point. Thus the output is the required electrical power exploited for control of the ventilation system.

Fuzzy implication: The six input fuzzy error with triangular membership functions to linguistic variables namely, 'Low', 'SL' (Small Low), 'Ok', 'SH' (Small High), 'BH' (Big High), 'High' is used and also output for required output power 'OFF', 'S'(Small), 'REG' (regular), 'SB' (Small Big), 'BB' (Big Big), 'ON'. Mamdani implication method is employed with approximate rule base reasoning (Fig. 7) Along with commonly used centroid de-fuzzified method. The power will be compared to the master controller to adjust the actuator according to the power available in order to maintain the indoor CO_2 concentration comfort negotiated (Fig. 8).

The fuzzy plot in Fig. 8, for the air quality control with the steady low power instrument with the limited standard occurrence of CO_2 concentration and as the concentration increases, the actuator power demand rapidly enhanced the minute rise in concentration.

CONCLUSION

Building energy management with intelligent control can contribute the huge amount of energy savings and cost. The study presented the comfort index of inhabitants according to the power consumption pattern to make the wise decision of energy management though fuzzy logic controller. The intelligent fuzzy inference slave control agents are provided to both wire or wireless actuator network for intellectual decision making. In order to maintain balance between the conflict of the user comfort and the total energy consumption as target to the sensors. Thus, achieving energy conservation and occupant comfort simultaneously. The learning and weighted decision making are kept in view of consumer comfort is the target to achieve. This will make consumers aware properly to take wise actions accordingly. In future, the builtin fuzzy controller will be employed with the appropriate algorithm to deal with the effective management to achieve building energy efficiency.

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